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PART 16. DISEASE RESULTING FROM ASBESTOS EXPOSURE IN BUILDINGS

Asbestos-Related Abnormalities in School Maintenance Personnel

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The use of asbestos-containing materials (ACM) in public, residential, and commercial buildings in the United States has been widespread.[1] Custodians, skilled craftspeople, and occupants are some of the groups at risk for asbestos exposure as a result of deterioration, damage, attrition, or impact of friable ACM, or reentrainment of released and settled fibers. The nature and extent of exposure-related health effects are a function of both the level and duration of exposure. The degree to which fiber type (amphibole versus serpentine) and dimension contribute to risk remains a matter of controversy.

In 1983, a survey of ACM in Boston public school buildings was carried out in accordance with the regulatory requirements of the EPA.[2,3] In all, 129 schools were inspected and categorized on the basis of the presence, type, location, and condition of ACM: Priority I indicated serious disrepair, requiring prompt corrective action; Priority II, isolated, damaged ACM; and Priority III, intact, stable ACM. Distribution of schools by category is shown in FIGURE 1. The purpose of the present study is to investigate the occurrence of asbestos-related disease in building custodians at risk for exposure to asbestos in these schools and to determine the proportion of disease attributable to such exposure.

METHODS

Cross-sectional surveys of Boston public school custodians were carried out in 1987 (n = 52) and 1988 (n = 69). Subjects were active or retired members of the Boston Public School Custodians Association (BPSCA). Eligibility criteria were at least 20 years of service in 1987 and at least 15 years of service in 1988.

Medical Evaluation

Questionnaire. Detailed occupational, smoking, and respiratory histories and information about current medication were obtained. Occupational history in-

cluded questions about asbestos exposure (1) at jobs held prior to the start of work as a Boston public school custodian, (2) at part-time jobs held during the period of work as a custodian, (3) as a result of household contacts, and (4) as a result of geographic proximity to an asbestos source, such as a shipyard or asbestos-manufacturing facility. Information was obtained about the time period and duration of employment at individual schools and about the frequency of performance of specific custodial tasks, such as sweeping and dusting of plaster or insulation dust, patching or removing torn insulation on pipes or boilers, and maintenance of boilers. Proximity to major boiler overhaul operations was recorded in terms of number and duration of occurrences. Latency was computed on the basis of date of hire for those custodians with no known exposure to asbestos outside of their work as a Boston public school custodian, and on the basis of date of first reported exposure for those with outside exposure. Where doubt existed, exposure was presumed and subjects were classified accordingly.

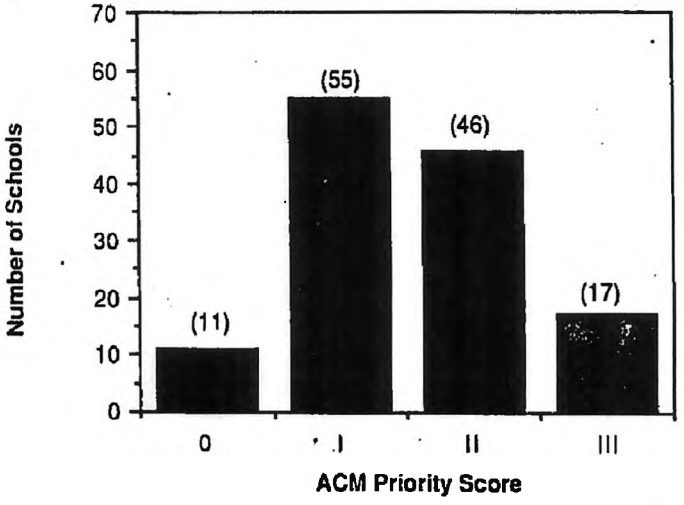

FIGURE 1. Distribution of inspected schools by asbestos-containing materials (ACM) Priority Score: 0 = no ACM; I = serious disrepair; II = isolated damaged ACM; III = intact, stable ACM. (From the Survey for Friable Asbestos-Containing Materials in the City of Boston Public Schools.[2])

Smoking and respiratory histories were taken from the Epidemiology Standardization Project questionnaire.[4] Dyspnea was graded according to criteria set forth by the Medical Research Council of Great Britain.[5]

Pulmonary function tests. Maximal expiratory flow-volume loops were obtained using the Eagle One Spirometer according to criteria set forth by the American Thoracic Society (ATS).[6] Maximal values for forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and FEV_1/FVC% were used. Prediction equations of Crapo and coworkers were used to derive predicted values.[7] A restrictive defect was defined as an FVC less than 80% of a value predicted on the basis of age, height, and gender together with an FEV_1/FVC% of 70 or greater; an obstructive defect was defined as an FEV_1 less than 80% of the predicted value together with an FEV_1/FVC% of less than 70.

Single-breath carbon monoxide–diffusing capacity (DLCO) was measured using the P. K. Morgan Modular Pulmonary Function Testing System (P. K. Mor-

gan Co, Kent, Sussex, UK). The average value of two acceptable maneuvers was computed and used in data analysis.[8] Prediction equations of Miller were used to derive predicted values.[9]

Chest radiographs. Posteroanterior (PA), lateral, and right and left anterior oblique (AO) chest radiographs 41 × 43 cm in size were taken in a mobile X-ray unit at full inspiration, 110 KVp, and a standard distance of 183 cm. Interpretation was carried out by a chest radiologist (R.G.) who was a NIOSH-certified "B" reader, according to the ILO-1980 system of classification.[10] Each chest film was re-read without knowledge of the initial reading by another "B" reader (L.C.O.) or an experienced "A" reader (N.L.S.). Differences were resolved by consensus reading. Definite pleural plaques were determined to be present when plaque-like thickening at the lung–pleura interface situated tangentially along the lateral chest wall or along the *en face* rib margin was 2 mm or more, or when typical plaque-like thickening was present along either hemidiaphragm.[11] When no pleural plaques were detected or when minor or suspect pleural abnormalities were observed, the pleural findings were categorized as normal. The presence of pleural plaque was judged on the basis of four views of the chest.

In order to determine the extent to which AO radiographic views increased the ability of chest X-rays to detect pleural plaques above that of PA and lateral views alone, the two "B" readers re-read 50 randomly selected PA/lateral film sets. The "re-read" was carried out one to two years after the initial reading, without knowledge of the initial 4-view reading. Classification based on two radiographic views was then compared to that based on four views.

Physical examination. Chest auscultation was performed by a physician (L.C.O. or N.L.S.). Dry end-inspiratory crackles that failed to clear with cough were recorded at each site at which they were heard. Height was measured without shoes; weight was self-reported.

Statistical Analysis

Student's *t* test was used to determine whether asbestos exposure, smoking, age, and body habitus differed significantly between those with and those without radiographic changes, pulmonary function test abnormalities, and dyspnea. Multivariate analyses were then used to examine the associations between exposure and pulmonary outcome, controlling for potential confounders. Logistic regression was used in the analysis of each dichotomous outcome and linear regression for each outcome described by a continuous measurement. A significance level of 0.05 was adopted.

RESULTS

Data analysis was carried out on 120 white males. One subject was excluded because of a history of medication with amiodarone, a drug associated with pulmonary fibrosis.[12] This person had pleural plaques and interstitial fibrosis of profusion grade 1/0 on chest roentgenogram. Of 197 eligible active school custodians, 102 (51.8%) were examined. Among those with at least 20 years in service since hire (n = 113), participation rate was 70.8%. The number of retired custodians examined was 18. Information on the number eligible was not available.

Age and exposure characteristics of the study population are shown in TABLE 1. Fifty-seven (47.5%) reported no exposure to asbestos outside of their usual

work as a school custodian (NOE). Most "outside exposures" occurred as a result of work at shipbuilding and ship repair or in building construction. Compared to the group as a whole, those with NOE were younger, with shorter duration of asbestos exposure and latency. Distributions by smoking category and pack–years of cigarette smoking were similar.

Chest Radiographs

Chest radiographs revealed pleural plaques (PP) in 40 subjects (33.3%). In 39 cases, PP were bilateral; in one case, unilateral. Diffuse pleural thickening occurred unilaterally in one individual with a history of pleural effusion. This case

TABLE 1. Age and Exposure Characteristics of Study Participants

	Total	Having No Outside Exposure	*p* Value[a]
n	120	57	
Age			
Mean	56.9 (7.8)[b]	55.2 (8.7)	0.0241
Range	38–77	38–77	
Years employed as a custodian			
Mean	26.1 (7.1)	25.7 (7.8)	0.5375
Range	6–46	6–46	
Latency (yr)			
Mean	31.3 (8.3)	26.8 (7.7)	0.0001
Range	17–49	17–46	
Duration of asbestos exposure (yr)			
Mean	28.6 (8.3)	25.7 (7.8)	0.0003
Range	6–48	6–46	
Pack–years			
Mean	30.1 (31.5)	28.2 (29.0)	0.5337
Range	0–184	0–141	
Smoking category			
Nonsmoker	25 [20.8]	11 [19.3]	0.514
Ex-smoker	63 [52.5]	33 [57.9]	$\chi^2 = 1.331$
Current smoker	32 [26.7]	13 [22.8]	

[a] No outside exposure vs. outside exposure.
[b] Standard deviations are in parentheses; percentages are in brackets.

was not included in the group with PP. Exposure associations are shown in TABLE 2. Of the group with NOE, 12 (21%) had PP. Duration of asbestos exposure and latency were greater in those with PP compared to those without PP. Multivariate analysis revealed a significant association between the occurrence of PP and duration of asbestos exposure ($p = 0.0265$) and latency ($p = 0.0146$) for the group as a whole, controlling for smoking. For those with NOE, PP were associated with duration of work as a school custodian ($p = 0.0155$) and latency ($p = 0.0163$). Pack–years of cigarette smoking were similar in the groups with and without PP ($p > 0.7$) in univariate analysis and were not associated with PP ($p > 0.9$) in multivariate analysis.

Other factors were examined as potential confounders. Among those with PP, there were no reports of pneumonia, pleurisy, chest injury or surgery, or medication with agents known to be associated with pleural fibrosis. Weight (kg)/height

TABLE 2. Chest Radiograph Results in Boston Public School Custodians: Exposure Associations

	Pleural Plaques	No Pleural Plaques	*p* Value
	n = 40, [33][a]	n = 80, [67]	
Outside exposure			
Yes	28 [44.4]	35 [55.6]	0.007
No	12 [21.0]	45 [78.9]	$\chi^2 = 7.368$
Years employed as custodian			
Total group	27.7 (7.4)	25.4 (6.9)	0.0891
NOE[b]	30.9 (7.9)	24.3 (7.2)	0.0082
Duration of asbestos exposure (yr)			
Total group	31.0 (7.4)	27.4 (8.5)	0.0221
NOE	30.9 (7.9)	24.3 (7.2)	0.0082
Latency (yr)			
Total group	34.4 (8.6)	29.7 (9.8)	0.0118
NOE	31.9 (8.2)	25.5 (7.0)	0.0088

[a] Percentages are in brackets, standard deviations are in parentheses.
[b] NOE = no outside exposure to asbestos.

(cm) ratios were similar in subjects with PP compared to those without PP—both for the group as a whole (0.49 vs. 0.48, $p = 0.4604$) and for the group with NOE (0.51 vs. 0.48, $p = 0.1447$).

Three subjects (2.5%) had small irregular opacities on chest radiograph of profusion grade 1/0 by the ILO-1980 system. All reported outside exposure to asbestos.

Pulmonary Function Tests

Mean values for measured variables of pulmonary function are shown in TABLE 3. The group with a history of outside asbestos exposure had a trend toward

TABLE 3. Pulmonary Function Test Results in Boston Public School Custodians

	Total	Outside Exposure		*p* Value[a]
		No	Yes	
FVC				
Liters	3.8 (0.8)[b]	3.9 (0.8)	3.7 (0.7)	0.0873
% Predicted	85 (13)	86.6 (13)	82.9 (13.9)	0.1328
FEV_1				
Liters	2.9 (0.7)	3.0 (0.7)	2.8 (0.7)	0.0354
% Predicted	82 (17)	85.4 (15.4)	79.8 (17.2)	0.0652
FEV_1/FVC, % DLCO	77 (8)	78.5 (7.3)	75.9 (9.1)	0.0934
ml/min per mmHg	27.2 (5.5)	28.3 (4.8)	26.1 (6.0)	0.0278
% Predicted	87 (17)	90.1 (16.4)	84.2 (18)	0.0622
Restriction	22 [18.3]	10 [17.5]	12 [19]	0.832
				$\chi^2 = 0.045$
Obstruction	19 [15.8]	8 [14]	11 [17.5]	0.608
				$\chi^2 = 0.263$

[a] No outside exposure vs. outside exposure.
[b] Standard deviations are in parentheses; percentages are in brackets.

lower FEV_1 and single-breath DLCO compared to those with NOE. The proportion with restriction and obstruction was not significantly different. In logistic regression analysis, restriction was positively associated with duration of asbestos exposure, both for the total group ($p = 0.0044$) and for the group with NOE ($p = 0.0420$), controlling for cigarette smoking. The single-breath DLCO, % predicted, was lower in the group with restriction (78.5 ± 21 vs. 88.9 ± 16, $p = 0.0108$). Linear regression analysis revealed a negative association between DLCO, % predicted, and restriction ($p < 0.02$), taking into account asbestos exposure and smoking.

Other

Twelve subjects (10.1%) reported symptoms of dyspnea of grade 2 or greater. The percentage was higher in the group with outside exposure (12.9%) compared to those with NOE (7%), but the difference was not significant ($p = 0.287$, $\chi^2 = 1.135$). In multivariate analysis, dyspnea was associated with duration of asbestos exposure ($p = 0.0346$), taking into account pack–years of cigarette smoking ($p < 0.7861$) and pleural plaques ($p = 0.3651$). Crackles at two sites or more on chest auscultation occurred in 6.7% ($n = 8$) of the total group: 11.3% of the group with outside exposure, 1.8% of the group with NOE ($p = 0.038$, $\chi^2 = 4.307$). There was no significant association between crackles and asbestos exposure ($p = 0.6647$), smoking ($p = 0.5327$), or restriction ($p = 0.2556$) in logistic regression analysis, controlling for each of the other variables.

One study participant subsequently developed malignant mesothelioma. In addition to his work as a school custodian for 32 years, he reported employment as a sheet-metal worker in a naval shipyard for 6 months in 1942. His chest radiograph revealed PP.

DISCUSSION

Pleural plaques revealed by chest radiography are a marker of asbestos exposure, both occupational and environmental.[8,9] Reported background prevalence figures vary from 0.003% in Australian adults over the age of 40, to 1.6% in nonexposed university employees in Paris, to 1.8% in a group of university laboratory technicians, maintenance personnel, and grounds workers in the northeastern United States.[13–15] In the present study, asbestos-related PP as revealed on chest radiographs occurred in 33% of a group of public school custodians who worked in buildings with friable ACM. Thirty percent ($n = 12$) of those with PP had no known exposure to asbestos outside of their usual work as a school custodian. PP were positively associated with duration of work as a custodian. Pulmonary restriction occurred in 10 (17.5%) of the group with NOE.

The health risks associated with exposure to asbestos from friable ACM in buildings are undetermined. Levels of exposure depend upon (1) the nature of the association with ACM (direct vs. indirect), (2) the nature of the ACM (friable vs. nonfriable), (3) the condition of the ACM (stable vs. damaged, deteriorating), and (4) accessibility. In general, custodians in buildings with ACM are likely to accrue higher doses of asbestos than are building occupants such as teachers and students. Exposure assessment in a university library with a deteriorating sprayed asbestos ceiling using phase contrast microscopy (PCM) revealed that dusting produced an average level of 4.0 f/cm^3 for custodians, compared to 0.3 f/cm^3 for

proximate library users.[16] Cleaning and moving books in the stack area resulted in levels of 15.5 f/cm^3; removing a ceiling section resulted in levels of 12.7 f/cm^3; and sweeping and dry dusting resulted in levels of 1.6 f/cm^3. Our finding of radiographic evidence of asbestos-related pleural plaques in school custodians without other known exposure is consistent with these levels of asbestos exposure and with their mean duration of school employment of 26 years.

An excess of PP compared to background was observed by Young and associates in maintenance workers in nonasbestos factory buildings with ACM around steam and hot water pipes and boilers (6.1% [n = 13] compared to 0.003%).[13] Only one of the 13 with PP had prior asbestos exposure; 12 had worked at least 20 years. Lilis and colleagues observed asbestos-related PP on chest radiography in 37.5% of maintenance workers in a large chemical plant in New Jersey.[17] Although the group studied included skilled tradespeople, 58% (n = 108) reported "bystander" exposure only. Thirty percent of this group had abnormal chest radiographs. There was no significant difference in outcome in those with and without a history of prior asbestos exposure.

The occurrence of PP in our study was comparable to that of Lilis and in excess of that reported by Young and Cordier.[13–14,17] Our finding of prevalence was based on four radiographic views of the chest, while those of Cordier and Lilis were based on a PA view alone. Young obtained both PA and lateral views.

TABLE 4. Pleural Plaque Prevalence in Boston Public School Custodians: Contribution of Anterior Oblique Chest Radiographs

Radiographic Views	Pleural Plaques		Prevalence
	Yes	No	
Posteroanterior, lateral	10	40	0.20
Posteroanterior, lateral anterior obliques	19	31	0.38

The extent to which AO chest radiographs aid in the diagnosis of asbestos-induced pleural disease varies, depending upon the diagnostic criteria applied and the underlying risk of the population examined.[11,18] In the present study, the addition of AO radiographs resulted in a finding of PP prevalence which was greater by a factor of 1.9 in 50 film sets (TABLE 4). Prevalence which was greater by a factor of 1.9 in 50 film sets (TABLE 4). Prevalence of PP was 38% using four views and 20% using two views in the subset that was reexamined.

In 18% of our study population, pulmonary function tests revealed a restrictive defect. Its incidence was similar in those with and without outside exposure to asbestos and was associated with duration of asbestos exposure in both groups. This prevalence of restriction was greater than that observed by Lilis and associates, who found restriction (FVC % predicted $\leq$ 79) in 5.4% of maintenance workers examined.[17] Cordier and colleagues found FVC and FEV_1 to be significantly lower in the group with occupational exposure to asbestos in buildings, but neither they nor Young reported the occurrence of restriction in their study populations.[14,13] The significance of our finding is unclear. Single-breath DLCO was lower in the group with restriction and was negatively associated with restriction in multivariate analysis. Restriction occurred more commonly in those with crackles, but the number with both abnormalities was small. These findings suggest the presence of occult interstitial fibrosis, possibly related to exposure to

asbestos and/or some other as yet unidentified substance in the work environment of school custodians.

Potential weaknesses of the present study are (1) the voluntary nature of participation, (2) lack of an unexposed comparison group, and (3) possible misclassification with regard to outside exposure status. Voluntary participation can introduce selection bias. To address this issue, we characterized nonparticipants by age and seniority at the time of the study. Participants and nonparticipants were similar in age: 55.4 ± 7.2 years vs. 54.5 ± 9.4 years, $p = 0.4648$. Years since hire (seniority) were 19.5 ± 5.8 for nonparticipants, while years worked as a custodian were 25.4 ± 6.8 for participants ($p = 0.0001$). This difference was largely attributable to the difference in the number whose eligibility was determined on the basis of 15 years' seniority. For participants the number was 22 (18.3%); for nonparticipants, 61 (64.9%). For those with at least 20 years' seniority, the participation rate was higher and participants resembled nonparticipants with regard to both age (56 and 59 years, respectively; $p = 0.0587$) and years of custodial work (28 and 26 years, respectively; $p = 0.1536$).

An external referent group was not available for comparison. Because of a high degree of interschool mobility and homogeneity of the study population with regard to performance of custodial tasks, the identification of an internal comparison group was not possible. Fortunately, data were available on prevalence of PP in a group of 717 laboratory, maintenance, and grounds personnel in a large university in Boston, Massachusetts.[15] None had known of any exposure to asbestos at the university. Prevalence of PP was 0.7% if 8 subjects with prior occupational asbestos exposure were excluded. Using this group for comparison, we conclude that the occurrence of PP in our study population was excessive, taking into account the increment in observed occurrence attributable to the use of AO radiographs.

In order to minimize misclassification with regard to outside asbestos exposure, we contacted those subjects who reported "Don't know" in response to specific questions about asbestos exposure or who reported work at jobs for which the likelihood of asbestos exposure was uncertain. In these cases, telephone interviews were conducted by one of the authors (L.C.O.) to obtain more detailed information about job responsibilities and workplace exposures. When doubt about asbestos exposure status could not be resolved, subjects were considered to have had outside exposure for purposes of data analysis.

In summary, the present study reveals evidence of asbestos-related disease in a group of public school custodians. Our results suggest (1) that pleural plaques as revealed by chest radiography are in excess of background, taking into account the incremental effect of anterior oblique radiographs on findings, and (2) that pleural plaques are attributable to asbestos exposure in public schools in a subset of the study population. Our findings indicate that prudent management or removal of friable ACM in buildings is important to the prevention of asbestos-related disease.

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